THE

PRINCIPLES AND PRACTICE

OF

COLLIERY VENTILATION.

BEING A TREATISE ON THE

LAWS GOVERNING THE MOTION OF AIR IN MINES,

AND AN EXPLANATION OF

THE FURNACE AND VACUUM FAN SYSTEMS

OF VENTILATION.

BY

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PREFACE.

THE ventilation of a colliery is so important a matter, and so severely insisted upon by legislation that it is a matter of great necessity that engineers, and more especially their subordinates, should thoroughly understand the laws of nature which govern the motion of air through pipes, and the majority of works on Ventilation in Collieries are written on the assumption that the reader is well acquainted with Physics, and the Mathematical knowledge required to understand them is of such a high standard, that the overmen and firemen of a colliery are compelled to work by rule of thumb. My object in compiling this work has been, therefore, to try and render intelligible to young mining engineers and the sub-officials of a colliery the laws which govern the motion of the air in Mines. Technical knowledge is of no use whatever, if it is not based on some sort of scientific truth to start with, and I wish to call the attention of workmen to the chapter on the expansion of gases in volume under change of temperature, and to caution them that, as shewn by the chart of observation, the gas may be brought down on the roadway by a change in temperature. Some measurements and formulæ are given in the French Metric System for simplicity's sake, and are not of actual necessity to English Miners. I have not entered into the use of fire-damp indicators in Mines, as I am thoroughly opposed to their use. Either we must depend on good ventilation, or on the indicator; it is obvious therefore that the former is to be preferred, since if the latter indicates the presence of gas, we require the former agent to disperse it; then, why have the latter?

CHAPTER I.

General Principles of Ventilation in Collieries.

CORRECTIONS & ERRATA.

Page 7, lines 25 and 26, read—"*To understand the general features of the construction of a furnace is a very simple matter.*"
Line 28—"practise" read "practice."
Page 12, line 16—"a general rule."
Page 15, line 15—for "abvise" read "advise."
Page 24, line 14—for "produces" read "produce."
Page 27, line 3—for "principal" read "principle."
Page 35, line 40—for "especially" read "especial."

motion and the velocity of the whole of the air in the tube will also continue constant, and in one and the same direction.

We propose treating of the Furnace system first—This system is only an artificial development of the natural laws of ventilation.

If air is heated under a constant pressure it expands $\frac{1}{459}$ of its volume at the temperature of Zero of Fahrenheit's Thermometer, and it can easily be understood that if the mean temperature of the Upcast Shaft is artificially increased, the heated air becomes lighter, bulk for bulk, than that in the Downcast Shaft; the consequence being that the heavier air column in the Downcast Shaft overcomes the lighter air column in the Upcast, forcing the latter up the shaft before it, and if we were to

prolong the Upcast Shaft to an indefinite length, the heated column of air would stand, possibly 60 feet higher than the level of the top of the cold air column. This difference is called the "Head of Air." The cool air, taking the place of the heated air, passes over the furnace in its turn, and so a perpetual current is kept up by the cool air going down one shaft and forcing the heated air up the other before it. It will be observed that the deeper the Upcast Shaft the more rapid will the draught be, and that the secret of a brisk circulation of air in the Upcast Shaft lies in the whole of the heat from the furnace being applied directly to increase by its action the temperature of the air column in the Upcast Shaft, and so set it in motion. The dumb drift should therefore be as short as possible, as far as is consistent with safety. The best method of laying out the furnace is as follows :—

Near the bottom of the Upcast Shaft the main return air-way, is split into two ways ; the furnace is placed in a recess, cut out in the face of the smaller split of the main return air-way, the main return itself enters the Upcast Shaft a little below the smaller drift ; by means of a damper placed in front of the furnace, the amount of air necessary to support the combustion of the furnace is regulated. The result is that no more air than is actually necessary is consumed, and the remainder has access to the Upcast, by way of the main drift below the smaller one ; by arranging the depth of the furnace below the entrance of the main return air-way and furnace drift, the supply of air and the temperature of the Shaft may be so kept uniform, that men may travel in the Shaft. It must be borne in mind, however, that this system is fraught with danger. In the first place if the cage becomes fast in the Shaft, the men would be suffocated, and the ventilation of the mine very seriously impaired, and any blower of gas that may be present in the pit would cease to become diluted, and would ultimately charge the partially choked Upcast Shaft like a gun-barrel, until it became ignited at the furnace. If, however, it is absolutely necessary to use the Upcast Shaft as a drawing shaft, then air doors should be fitted to the shaft to close at the furnace drift, and in the event of an accident they should be promptly closed and the fires damped out. Care must be taken in erecting these doors, to allow for the expansion of the iron guide blocks, or when the furnace is burning

they will not close just at the critical moment. On the whole, travelling in the Upcast Shaft is an economical practice that should be avoided. It will naturally occur to the reader to ask, why the two air columns, if of the same temperature, but of different diameters, or rather sectional areas, balance each other. It must be evident, that the weight of a column of air, like that of a column of water, is directly as its height, and that whatever extra pressure exists on the area of the smaller column of air, by reason of the greater dimensions of the larger column, is really exerted, not on the sectional area of the smaller column, but on that part of the mine where the area of the larger column becomes diminished to the area of the smaller one, such as the sides of the air-ways. In this way equilibrium is preserved. The elements of success, therefore. in furnace ventilatiou, are as follows :—

The Upcast Shaft should be free from obstruction, the deeper of the two, and every pound of coal consumed in the furnace should do its share of work in setting the hot air column in motion ; no more air should be admitted to the furnace than is absolutely necessary to support combustion, and the temperatures in the two shafts should differ considerably, yet uniformly. Checks on the temperature, or careless firing will check the air current, and this is to be avoided. We must consider, therefore, some of the laws, which govern the mechanical properties and effect of heat, in order to proportion our furnace to our requirements.

Coal is composed of Carbon and Hydrogen, and some other substances that are not necessary for our consideration. 2¼lbs. of coal require 29 cubic feet of air to insure complete combustion ; this is on the supposition that the whole of the Oxygen contained in the air is converted by combination with the Carbon into Carbonic Acid Gas ; but in practice it will be found that the best furnaces only burn half the Oxygen of the air passing through them, so double the amount of air must be provided. The process of burning is this: the greater part of the Carbon is transformed into Carbonic Acid Gas, the remainder into Carbonic Oxide : the Hydrogen combines with the remaining Oxygen to form steam. A remarkable feature of the case is that at equal temperatures the volume of the gases resulting from combustion is nearly equal to that of the air passing through the furnace. It is therefore of no importance in calculating the effective force

of a furnace, to ascertain whether all the air has been consumed in passing over the furnace or not. The same volume of air will be obtained whether the air has passed the furnace or not; that is to say, the quantity of air admitted to the furnace will not be appreciably diminished in bulk by passing through the furnace. From these facts the following formula has been obtained.

A volume of air V arriving at a temperature t at the furnace.

In the Upcast Shaft when the temperature is represented by t^1

then $V = \dfrac{v^1 + a\,t^1}{1 + a\,t}$

This shows that it increases in volume, in a proportion due to its temperature, and to no other agency.

The next question is, what is the difference of weight due to the difference of temperature in the two columns. In Mining Engineering the difference is called the *head of air*, or *motive column*, since it is the exact Mathematical representation of the force exerted to produce the motion of the two air currents. This case is found as follows :—

Let H = Head in feet.
D = Depth of Downcast Shaft in feet.
t = Temperature of Downcast Shaft.
T = Temperature of Upcast Shaft.

$$H = D\,\frac{T - t}{T + 459}$$

Or representing the difference of the two temperatures by x.

$$H = \frac{-Dx}{T + 459}$$

Or a simpler method of obtaining the same result, is found as follows :—

Let D Represent the length of the downcast column of air.
U = Length of Upcast ditto
T = Number of degrees in excess of 32° F in D.
t = Ditto in Upcast.

$$U = D\left(\frac{480 + t}{480 + T}\right)$$

To give the length of the Upcast; then $U - D$ will equal the *head* H, and $8\sqrt{H}$ will give the velocity of the air current in feet per second, in the Upcast Shaft.

This result H will represent the power we have from our furnace to impart motion to the air column, and can be converted to inches of water gauge, as follows :—

A column of water in millimetres of water weighs per square metre 1 kilogram, and a column of air of a temperature of t in metres weighs p per metre in height. H expressed in metres of air at a temperature t^{1} can be represented in kilos per square metre, by the product of H multiplied by the weight of 1 cubic metre of air, at a temperature of t^{1}, or by $p \dfrac{1 + a\,t}{1 + a\,t^{1}}$

Let $H =$ the height in water gauge readings in millimetres, then,

$$h = H \frac{a\,(t^{1} - t)}{1 + a\,t} \times p \frac{1 + a\,t}{1 + a\,t^{1}} \qquad (I.)$$

$$= p \,.\, H\,a \; \frac{t^{1} - t}{1 + a\,t^{1}}.$$

from this equation t^{1} may be extracted

$$t_{1} = \frac{h + p \,.\, H \,.\, a \,.\, t}{a\,(p\,H - h)} \qquad (II.)$$

A millimetre being 0·039370 of an inch, this may easily be converted to the English reading.

Equation I., gives the mean temperature at which the air should ascend to produce a reading h in millimetres of water.

Equation II, demonstrates that as the temperature increases, the value of the depression becomes less as the temperature increases.

The calorific capacity of air was determined by M. Regnault, and is represented by 0·237. So that to raise 1 kilogramme of air 1° centigrade, 0·237 kilos. of heat will be required.

The calorific power of coal varies with its composition, but to no very great extent; as a general rule it may be estimated that 1lb. of coal will circulate 13,000 cubic feet of air. M. Devillez states that 1 kilogramme of small or slack coal will produce 7500 units of heat; a kilogramme being 2lbs. 3¼oz.

It is now necessary to know what velocity is acquired for a given known difference in temperature between two shafts, or for a given head. M. Peclet has worked out these calculations, and they are applicable to the requirements of the viewer, as they are based on sound scientific principles.

He admits that the temperature will be 300° in the Upcast; that 18 cubic metres at 0° cent. will be required to burn 1 kilo. of coal, and he applies this hypothesis that the chimney will be

20 metres long, preceded by a horizontal drift of the same sectional area and 20 metres long, making a total distance to be travelled of 40 metres between the furnace and the top of the chimney.

Then we can calculate from the above, the value of the constant *U*.

To burn 50 kilos. of coal per hour.

$\frac{18\ m^3\ 50\ kil.}{3600\ ''} = 0{\cdot}25$ cubic metres of air, at 0° cent. per second.

These 0m³ 25 cubic metres of air, will expand to *c* volume of

$$0{,}25\ (1 + 0{,}00366 \cdot 300^\circ)$$
$$= 0{\cdot}529 \text{ cubic metres}$$

At a temperature of 300° cent.

The sectional area of the drift is

$$0{\cdot}785\ (\quad , 3272)^2 = 0{\cdot}084,\ 19 \text{ metres.}$$

The perimeter is $2p^m$ 1636

$$= 1m\ .\ 027.$$

The mean velocity of the air current is

$$V = \frac{0m^3,\ 529}{0m^2,\ 084}$$
$$V = 6m.29.$$

The depression corresponding to this velocity throughout the drift of 40 metres long, will be

$$h = n\ \frac{L.D}{S}\ y_2$$
$$= n\ \frac{40 \cdot 1,\ 027}{0,\ 084}\ (6{,}29)^2$$
$$= n\ .\ 19346.$$

The friction increases as the square of the velocity of the air current, and therefore the *velocity* of the air current will effect the *quantity* of coal consum ed in the furnaces.

The causes of the loss of power with Furnace Ventilation are very numerous. M. Devillez proposes to allow double the necessary quantity of coal consumed as a compensation for the loss caused by the cooling force of the sides of the shaft, and the extra weight of the column of air in the Upcast, due to the presence of carbonic acid gas and steam. From the foregoing, the principles of success in the construction of furnaces may be deduced, bearing in mind that from 13° to 20° *F* variation of

temperature between the Up and the Downcast Shafts will suffice to maintain a brisk draught, and that the whole of the heat evolved by the combustion of the fuel, must, if possible, be applied directly to heat the column of air in the Upcast Shaft. The Pumping Shaft should be generally used, if possible, for the downcast air current, on account of the great absortion of heat that would take place, were the furnace place at its foot. On account of the increase of the surface temperature, and therefore of that of the downcast current, a brisker fire will be required in Summer and the reverse will take place in Winter. When the pit is not fiery, and the Upcast is used solely as an air shaft, and no drawing takes place in it, the furnace may be placed in the main return air-way, which may be enlarged and terminate in the furnace; if the road is through rock, or non-combustible strata, a single arch of brick will suffice, but if the returns are in the coal measures, great care must be taken to prevent, not only the ignition of the coal through the extreme heat, either directly or by spontaneous combustion, but also the expansion of the gas in the seam, and the development of a blower at the very spot where its presence is most dangerous. In this latter case two concentric arches with a space of at least 5 feet must be erected; the space may be well packed with sand. The upper arch will support the rock, and the lower one the bed and grate of the furnace.

Fig. 1. shews the general features of the construction of a furnace, which is a very simple matter, if the principles and precautions inculcated here form the basis on which the design is prepared. In general practise, the formula

$$H = D \frac{T - t}{T + 459}$$

which gives the ***head*** of air columns, will be sufficient to enable the engineer to calculate the dimensions of the furnace, and, in laying down the ventilation of a colliery, the following are the steps to be taken which are explained in the following chapters.

The size, length of the airways, their number, the nature of the coals, number of men and horses employed, nature and quantity of goaf (if any), friction, powder smoke, and some other minor details have to be considered first.

The formula are to be worked out, and the result arrived at will be that a *given volume of air per second will be found necessary,*

whether the ventilation be produced by means of a fan or furnace. This point *must* be arrived at, and neglect or mistakes in calculating it have been the cause of the most disastrous colliery explosions.

The question will then arise, viz.: which system will be the best to use, and what are the dimensions required to produce this known quantity of air per second? This chapter has been devoted to the laws affecting the above question, when the upcast furnace is used; the following chapter is devoted to the fan and its general principles.

For all general purposes the following formula will be found useful when furnaces are to be used.

Add 461 to the temperature of the air in the Downcast Shaft. This will yield the absolute temperature; the volumes will then vary as the temperature.

To find the velocity of the air current in feet per second for a known head of air, the following will be found useful.

Let H be the difference of height in each air column or shaft, V the velocity in feet per second.

$$H = \text{head of air in Upcast in feet.}$$

$$V = 8\sqrt{H}$$

then if the Downcast Shaft air column is equal to 1000ft., and the Upcast air column$=$1400

$$400\text{ft.} = \text{head of air.}$$

$$H = 400.$$

$$8\sqrt{H} = 8\sqrt{400.}$$

$$V = 8\ (20).$$

$$V = 160\text{ft. per second.}$$

CHAPTER II.

The Vacuum Fan.

Of late years considerable apprehension existed in the minds of engineers respecting the use of a furnace in the pit; danger was always present from gas firing at the furnaces, and, after an explosion difficulty was frequently experienced in re-lighting the furnaces. M. Guibal proposed to create a circulation of air in the mine by means of the rapid rotation of a Fan; this method of creating ventilation has been largely adopted in collieries, and the following data may be taken as indicative of the comparative cost of the Fan and furnace systems; but it must be remembered that there are occasions when the furnace is preferrable to the Fan and *vice versa*, and that no general rule can be laid down as to which system is to be used; it must be determined on by the engineer, after due deliberation on the circumstances and exigences of the particular case. The Fans now used exhaust the air from the top of the upcast shaft, or at the end of the return air course where they are employed for day-light working. They are divided into two classes; those which keep up a continuous current by centrifugal action as Guibal's Fan, and those which intermittently discharge a given quantity of air as the kind of rotary pumps invented by Cooke and Lemielle. One of the main objects of M. Guibal's Fan is to have as low a final velocity as possible in discharging the air from the pit; because whatever excess of velocity there may be in the discharged air beyond the velocity of the ascending current is simply waste of power. The Fan must be worked with the exact area of discharge opening that is suited to the quantity of air to be discharged. If the discharge opening be too large, there is waste of power, since useless air is put into motion. If the opening be too small, the discharged air meets with a resistance, which also causes waste of power.

At Rugeley and Cannock Collieries one pit 160 yards deep, the air circulated by the Fan is 103·3 cubic feet per minute, the water-gauge shews 0·86 inches at bank and 0·62 inches in the pit.

The following tabulated statement shews the comparative cost of Furnace and Fan under similar conditions:—

Name of Mine.	System.	Coal per H.P. in lbs. per hour.	Cost per H.P. in pence per hour.	Coal required per twenty-four hours.	Cost of Coal per annum.
					£ s. d.
Tyne Main ...	Furnace	43·45 lbs.	·582 *d.*	3·67	166 9 6
Hetton.........	„	59·60 „	0·798 *d.*	3·34	152 0 0
Pelton	Fan	12·30 „	0·165 *d.*	1·03	47 0 0
Elswick	„	10·40 „	0·135 *d.*	0·87	39 17 6
Whitehaven...	„	10·70 „	0·143 *d.*	0·89	40 17 6
Sacré Madame	„	12·30 „	0.165 *d.*	1·03	47 0 0

These data as far as regards the furnace system, are rather inaccurate as to cost, as the furnaces are of rather antiquated origin, and of late years have been very considerably improved.

If V = Radius of the circle against which the shutters of the fan are fixed.

R = Radius of the hollow cylinder of the fan.

M^1 = Mass of air contained within the two adjacent shutters $x\ z$—$z\ n$, and between the two cylindrical surfaces.

M'' = Mass of air contained between the same two shutters, and between the second and third cylindrical surface, at a distance of Z^1 from the centre.

M = Mass of air contained between the last two cylindrical surfaces at a distance R from the centre.

Let us suppose the rotation round its centre O of the cylinder to be of a uniform speed V, the volume of air contained within the cylindrical surfaces will be impelled by the shutters, and will be acted upon by the rotary motion of the fan, then the following will denote the centrifugal force developed.

The centrifugal force developed by the Mass $M^1 = M^1\ V^2 z$,

That developed by the Mass $M'' = M''\ V^2 z^1$ giving a result for the Mass M, $M = M\ V^2\ R$.

In general practice it will suffice to erect a fan guaranteed to give a certain result: the makers of Vacuum Fans have results which will be sufficiently accurate to go by, and the velocity of the air can be regulated by air regulators; on no account what-

ever must the regulators be placed in the intake currents, or Downcast Shaft as the air being drawn out of the pit at a greater speed than it enters it, a depression will be caused that may produce a blower of gas.

A duplicate engine must be attached ready for use in case of a breakdown, and the engine must be properly governed to run steadily at any speed. Care must also be taken to construct a drift to the fan from the Upcast Shaft, so that in the event of an explosion, the fan itself and its gear may not be damaged. There are so many forms of Centrifugal Ventilators and Vacuum Fans, that a description of all would be impossible; the following Chapter will give the rules (expressed arithmetically) to find the cubic feet of air per minute required to ventilate the pit, and the fan must be guaranteed by the manufacturer to yield this result with a fair margin, in case of emergency.

Phosphor bronze bearings in the fan itself will be found an economy, and great attention should be paid to the trimming of the oil cups, the firing of the engine, and the air doors in the pit, or the fan is no economy over the furnace.

In designing Centrifugal Fans, the following rules may be observed for proportions. D = diameter of Fan, V = velocity in feet per second of the tips of the Fan blades. P = pressure in lbs. per square inch.

$$V = \sqrt{p \times 97300}$$

$$P = \frac{V^2}{97300}$$

Length of Vane $= \frac{D}{4}$ Diamater of Centre $= \frac{D}{2}$

Width $= \frac{D}{4}$ Eccentricity of Fan $= \frac{D}{10}$

CHAPTER III.

The Laws of Chemical Combination as Applied to Combustion.

In calculating the velocity and quantity of the air current, the first thing we shall require to know is the rule for ascertaining the quantity of air required for the complete combustion of the principal form of fuel; and it will be noted that the method of proceeding to arrive at the result must be taken as the rule to follow in all other calculations of a similar nature. The laws of inorganic chemistry will be found to apply here, and a careful perusal of the laws of chemical combination and affinity will enable the reader to arrive at a result with comparatively little labour. In the first place, the combination of any substances is simply their oxidation with the evolution of heat, and frequently light; such products as are compound products, for instance coal, cannot be entirely oxidised, *i.e.*, their combustion is not complete, and the residue is found in partially consumed particles; this we see in the smoke evolved from a furnace, and it may be taken as a general that the more complete the combustion the less the smoke.

There is no destruction of matter or loss in weight in combustion. For instance, a candle is lit and burned out; a small quantity of ash on the end of the wick is all that remains to the naked eye, yet the candle is not destroyed; the ingredients of the candle have combined in certain proportions with the oxygen and æriform products, viz., aqueous vapour and carbonic anhydride, weighing really *more* than the original candle. This gain in weight represents the exact quantity of oxygen absorbed and used in bringing about the combustion of the candle, and it would be found that the decrease in weight of a volume of air, sufficient to support the entire combustion of the candle, would be exactly equal to the increase of weight of the remaining products of the candle after combustion.

Four laws govern the combination of chemical substances.

I.—When one body combines with another in several proportions, the higher proportions are multiples of the first or lowest. Thus oxygen and hydrogen are contained in water in the following proportion :—

16 parts oxygen, 2 hydrogen.

The elements unite to form water. Here the proportion of oxygen is 32 to 2 parts hydrogen.

II.—The same substance always consists of the same elements united in the same proportion.

III.—If two bodies combine with a third body, they are multiples of the proportions in which they may combine with each other. Thus carbon unites with oxygen in the proportion of 12 parts by weight of the former to 16 of the latter. Hydrogen unites with oxygen, as already shewn, in the proportion of 2 to 16. Fire damp is a compound of carbon and hydrogen. Here 12 parts carbon are united with 4, or 2×2, parts of hydrogen.

IV.—The combining proportion of a compound is the sum of the combining proportions of its constituents. Thus sulphur peroxide is a combination of sulphur and oxygen in the proportions of 32 to 48, the sum of which is 80; water, of hydrogen and oxygen in the proportion of 2 to 16, the sum of the latter numbers is 18. When sulphur peroxide is added to water, it unites in the proportion of 80 parts of the former to 18 of the latter.

These laws will enable the reader to calculate all questions relating to combustion.

In ventilating a mine, therefore, we have to take into consideration all substances in the mine that will require oxidation, such as the human beings, or rather the human blood, that of the horses, the flames of the lamps, the dilution of the gases, the flame of the furnace (if any), and the gunpowder smoke. These items are the causes that draw on the ventilating current chemically; added to this we shall find that we have causes that affect the volume and velocity of the current mechanically. I propose to deal with these separately. They are both the most important features in ventilation. Neglect of these two features has caused the most disastrous explosions, and the only way to provide against their recurrence is to thoroughly master the scientific laws which govern the former item, and the mechanical and practical causes which affect the latter; having done this,

provision must be made for their joint demands, and they both insist on being provided for, in estimating the velocity and volume of the ventilating current. The means for producing the current must then be determined on, but, firstly, the effective power, whether of the furnace or the fan, as the case may be, must be decided on, on the basis of the formula previously given to arrive at the required result in these two chapters.

CHAPTER IV.

Chemical Interference with the Main Air Current.

The first and most important is the presence of fire damp, or carburetted hydrogen.

Its chemical composition is as follows:

1 atom of carbon to 4 atoms of hydrogen represents marsh gas. CH_4 is, therefore, its chemical symbol. Twice the amount of air renders it violently explosive, and an explosion of fire damp is thus represented chemically:—

$$\frac{2 \text{ vols.}}{CH_4} + \frac{4 \text{ vols.}}{2O_2} = \frac{2 \text{ vols.}}{CO_2} + \frac{4 \text{ vols.}}{2O\,H_2}$$

The 4 volumes of oxygen which 20 volumes of atmospheric air contain produce 2 volumes of carbonic acid and 4 volumes of steam; on the condensation of the steam, 16 volumes of nitrogen remain mixed with the carbonic acid. This product is the *after* damp. Here we have, then, a gas which possesses a great affinity for oxygen, and which, therefore, will weaken the effect of the main air current by absorbing a portion of its oxygen. In what proportion it will be absorbed, volume for volume, may be ascertained by the laws we have previously given affecting chemical combination.

To ascertain *how much air will be polluted by the coal gas is the first question;* this is calculated as follows:—The quantity of air discharged into the airways of a colliery will always bear a direct relation (i.) to the area of the surface of the coal, such as the roof, side, bottoms, &c., exposed to the action of the

ventilating current; (ii.) to the cubic contents of the coal wrought. Each piece of coal wrought discharges through its faces its small amount of gas. We must think of a small lump of coal as if it was a model coal mine.

To estimate the amount of air necessary to dilute the coal gas, we must proceed as follows:—1 cubic inch of coal yields, or is capable of yielding under an air pump, a volume of gas equal to its own bulk. 1 cubic foot of coal will yield 1 cubic foot of gas.

It will be seen by examining the nature of fire damp, that unless the gas is diluted with more than 15 times its volume of air, it will be explosive; therefore, $15 \times 1 =$ amount of air required to dilute the gas yielded by 1 cubic foot of coal.

The result is obtained by *multiplying the cubic contents of the coal in feet by* 15. The result is given in cubic feet of air. We abvise our readers to increase this number 15 to 100, to provide for contingencies, such as blowers, &c., then 100 cubic feet of air will be required for each cubic foot of coal wrought in the seam.

Next, we have the withdrawal of oxygen from the atmosphere in the pit, consequent on combustion, respiration, candles, lamps, and furnaces.

We have to allow for these as follows:—

If we have a furnace at the foot of the Upcast Shaft, then, since in oxidation 1 atom of carbon unites with 2 atoms of oxygen, following the laws of affinity in chemistry, we find that the atomic weight, or figure denoting the combining proportion of carbon is 12, that of oxygen 16.

The oxygen will be represented by 32, since there are 2 atoms of this gas, the carbon by 12.

$32 \div 12$ will give us the amount of oxygen required to oxydise a piece of carbon. Let us suppose then that 1lb. of coal is to be burnt in the furnace per second. Then $32 \div 12 =$ oxygen in lbs. per second $= 2\frac{2}{3}$lbs.

1lb. of hydrogen will require 8lbs. of oxygen by the same rule, for

1 being the atomic weight of hydrogen.
16 „ „ „ oxygen.

$$H_2O = \text{the product.}$$
$$\text{or } 16 \div 2 = \text{lbs. of oxygen.}$$
$$= 8\text{lbs.}$$

The composition of air inhaled and exhaled is given in the following table as a reference.

Before entering the lungs.		When exhaled from the lungs.	
Nitrogen ...	79·0	Nitrogen ...	79·0
Oxygen ...	21·0	Oxygen ...	17·5
	100·0	Carbonic Acid	3·5
			100·0

3½ units of oxygen are, therefore, extracted from the air by the action of the lungs, and applied to oxydise the carbon in the blood cells. A cubic foot of air breathed will be, therefore, vitiated by 3½ per cent. of carbonic acid gas; therefore, each person will discharge from their lungs into the mine $= 0·035 \times 60 = 2·10$ cubic feet per hour.

Medical authorities state that an average inhalation of air is represented by 1 cubic foot per minute, when the person is awake.

A horse breathes 6·3 times the volume per minute than a man.

$$\left.\begin{array}{c}·035 \times 6·3 \times 60 \\ = 13·230 \text{ cubic feet.}\end{array}\right\} \begin{array}{l}\text{cubic feet of carbonic acid per} \\ \text{horse per hour discharged into} \\ \text{the mine.}\end{array}$$

We have now to consider the effect of the lamp and candles, and the gunpowder. We shall then be in a position to estimate the total *chemical vitiation of the air of the mine for a given time.*

A candle or lamp produces about 2·51 cubic feet of carbonic acid per hour by experiment; this is shewn by the fact that if a candle is burned in a close vessel containing 1 cubic foot of air, ·20 of the volume of air is deprived of the oxygen, since it is reduced in bulk to that, or nearly that, extent. The proportion of oxygen in air is 21 per cent., therefore,

$$·20 \times ·21 \times 60$$
$$= \text{cubic feet vitiated per hour per light}$$
$$= 2·52.$$

I find, by experiment, that 2·51 is nearer the mark as an average reading. Let $x =$ No. of lamps used, then $2·51 \times x =$ air in cubic feet per hour vitiated by lamps, the rule being to multiply the No. of lamps used by 2·51.

Gun powder is our next source of vitiation and is a most important one, since the presence of nitrous fumes proves so very

detrimental to the health and the eyesight of men and horses in a Mine. Mr. André estimates the effect of ordinary blasting powder to be as follows:—

1lb. of powder produces 0·30lb. carbonic acid. 1 cubic foot of carbonic acid weighs .1164lb. per pound of powder consumed.

$\frac{\cdot 3000}{\cdot 1164}$ = cubic feet of carbonic acid gas discharged per pound of powder fired.

= 2·58 cubic feet per lb. of powder.

White damp or carbonic oxide is another source of evil, and is very often ignored by engineers.

Its affinity for oxygen is very great. It cannot be found with a candle, and here let me take the opportunity of warning well sinkers that to test the atmosphere of the shaft with a candle, is the most foolish and wrong proceeding; by all means test for the presence of carbonic acid gas with a candle, but it must be borne in mind that carbonic oxide is a *poison*; it does not suffocate, but actually kills men by its poisonous action on the blood, producing fainting and giddiness, and because a candle burns in a well it should never be assumed that the atmosphere is sufficiently pure for a man to live in it. An atmosphere of one per cent. of this gas is fatal to warm blooded animals. It is lighter than air, and will therefore be found in the roof, and will be detected by its peculiar odour; imperfect spontaneous combustion of wood and coal produces it; small explosions of fire damp in a large space produce it also. Fortunately, in estimating the volume of the air current, one may neglect to take into account the presence of carbonic oxide, as if precaution is taken it will not present itself.

We have now got possession of all the data to estimate the *total* amount of chemical vitiation as follows —

Firedamp allowed for as under:

1 cubic foot of coal requires 100 cubic feet of air.

Furnace 1lb. of coal requires $2\frac{2}{3}$ bulk of oxygen per second.

1 Horse	discharges	13·230	cubic feet of	Carbonic Acid	per hour.
1 Man	,,	2·10	,,	,,	,,
1 Lamp	,,	2·51	,,	,,	,,
1lb. of powder		2·58	,,	,,	,,

Added to this, we must allow for effluvia 2 cubic feet of air per minute per person.

2·10 cubic feet of carbonic acid, discharged per hou r pe man, must be diluted to allow the air in the pit to contain nor more than ·35 per cent. of carbonic acid, or the men would be gradually choked off. This will require 600 cubic feet of air. Each man requires 600 cubic feet of air per hour = 10 cubic feet per minute.

Then each lamp will require, by proportion, 720 cubic feet per hour, or 12 cubic feet per minute.

If each man has a lamp,

$$10 + 12 = \left\{ \begin{array}{l} \text{cubic feet of air per minute} \\ \text{for the men complete.} \end{array} \right.$$

10 + 12 + 2 = the amount, allowing 2 cubic feet for effluvia.
= 24 *cubic feet per minute per man and lamp employed.*

Horses :—

Each horse produces 6·3 times the amount of carbonic acid than a man.

As a general rule, 3 men equal 1 horse in air breathed.

$\therefore$ 3 × 24 = cubic feet per horse per minute.
= 72 cubic feet per minute per horse employed.

Mr. Andrè, in his able work on mining engineering, states that "the quantity of air required by eight men will be taken up by consuming 1lb. of powder," for reason set forth previously.

Assuming this to be correct, which may certainly be done,

8 × 24 = cubic feet of air per lb. of powder fired.
= 192 cubic feet per 1 lb. of powder fired.

In estimating the amount of air required for dilution as a factor of safety, 2, or twice the amount required, is just within the limits; when blowers exist, from 2 to 6 times the amount must be allowed.

Now the formula adopted by nearly all mining authorities to estimate the quantity of air required in cubic feet per minute per district, if the mine is divided off into districts, is

Q = quantity of air per minute in cubic feet.
M = No. of men at work in the mine.
H = ,, horses ,, ,,
P = lbs. of gunpowder fired per hour.
O = output, or quantity of coal raised per minute.
A = area of surface coal exposed to the ventilating current, in yards.

Then $Q = m\,24 + H\,72 + P\,192 + O\,100 + a.$

Where 1 ton of coal wrought = 1 cubic yard of coal.

Then if the output be 100 tons, the expression $O = 100$ cubic yards.

The average quantity of coal raised per minute, or output is thus calculated.

If the total output raised is 300 tons in 12 hours by, let us say, 60 men.

Each man raises 5 tons in the 12 hours.

$$720 : 1 :: 5$$

or $\frac{5}{720}$ of a ton per man per minute.

Then in a Mine where there are 400 men, 30 horses, and the coal surface is 1000 yards.

The output 600 tons per day of 12 hours, and the powder used 8lbs. per hour.

$$Q = 24\,(400) + 72\,(30) + 192\,(8) + 100\,(17\tfrac{2}{3}) + 1000.$$

$$Q = 9600 + 2160 + 1536 + 1766\tfrac{2}{3} + 1000.$$

$$Q = 16062\tfrac{2}{3} \text{ cubic feet per minute.}$$

CHAPTER V.

Mechanical Interferences with Velocity of the Air Current.

We have seen in the previous chapter that allowances must be made for the consumption of oxygen, vitiation of the remaining air, and the dilution of the gases, in estimating the *quantity* of the air current.

The *velocity* of the current will be affected by three things; *the friction of the air along the sides of the air-ways; the divisions of the main air current; and the position and extent of the stoppings and air doors.*

The friction of the air current will depend on the *area* of the rubbing surface traversed by the air; in the case of fluids, the friction is overcome by increasing the head, and the fall is thus calculated.

L = Length of Channel tube in yards.

A = Cross sectional area of the stream in square feet.

$P =$ Perimeter in feet.

$F =$ Fall or difference of level in inches of the two ends of the pipe.

$C =$ Cubic feet of water discharged per minute.

$$F = \frac{(\frac{C}{A})^2 \times L \times P}{874320 \times A}$$

We cannot however make a "fall" for the air current, but we can increase the "head" and the velocity of the air current must be sufficient, not only to overcome the friction, but to sweep the face of the seam sufficiently fast to secure good ventilation; a large volume of air at a medium velocity is better and safer ventilation for a fiery pit than a small quantity at a high velocity. The whole pit must be filled with *air*, and this can only be accomplished by a larger volume, if possible, than it will hold. At Haswell Colliery, $\frac{10}{11}$ of the ventilating pressure is spent in overcoming the friction of the air; the remaining $\frac{1}{11}$ creating the final velocity at the top of the Upcast Shaft; the amount of friction of the air can only be estimated by the amount of force required to overcome that friction, but since the friction is directly affected by the area of the rubbing surface, the pressure required to overcome the friction will be proportionate to the area of the rubbing surface, and if this area is multiplied by any number, the friction, and consequently the pressure required to overcome it, is increased in a like degree. To get the greatest effect with the least amount of friction, we required to find a figure whose perimeter or circumference will be least for the greatest sectional area.

The perimeter of a square is 4 when its sectional area is 1, but the perimeter of a circle is 3·1416 for an equal area of 1.

Then we should, if possible, use circular air-ways; the friction of any fluid, whether air, gas, or water, varies as the density of air, gas or water.

An air-way 4ft. × 5ft. has a perimeter of 20 feet; the perimeter multiplied by the length, gives the area or rubbing surface r.

$$r = p \times L$$

When r is the area, p the perimeter, and L the length.

So that if the above air-way was 1500 feet long, the rubbing surface would be 30,000 square feet; in an air-way 4ft. × 10ft. and of an equal length the rubbing surface $= 4 \times 10 \times 1500.$

$= 60{,}000$ square feet.

So that for *four* times the area there is only *twice* the extent of rubbing surface; if we divide this air-way into four equally small ones, such small air-ways will have a perimeter of 20 feet; therefore the total perimeter of the four air-ways is equal to $4 \times 20 = 80$ feet.

$$80 \times 1500 = \text{total rubbing surface.}$$
$$= 120000 \text{ square feet,}$$

the friction being double.

Therefore one large air-way is more economical than a number of small ones making up the same size as the large air-way, but frequently it is more convenient to have a number of small ways than one large one; a feature to be recollected in speaking of the pressure employed in ventilating a colliery is that it is the pressure in pounds per square foot that is meant, and that the pressure will depend naturally on the area over which it is distributed; for instance, 10 lbs. per square foot on an air-way containing 100 square feet is a *total pressure* of 1000 lbs.; in mining the pressure is reckoned in lbs. per square foot of sectional area of the air-way, as in mechanical engineering the total force acting upon the piston of a locomotive engine is obtained by multiplying the pressure per each square inch into the area of the piston.

The resistance to the air depends on the perimeter of the way, and the pressure per square foot necessary to overcome the friction will vary as the sectional area of the air-way, as in the steam engine.

The laws governing the friction of fluids in pipes are as follows:—

(i.) For a given section of an airway, the resistance from friction will increase directly as the length of the airway.

Thus, an airway, 5ft. × 4ft., has a perimeter of 20ft.; if the way is 10ft. long, the rubbing surface is 20 × 10, or 200 square feet; if the airway is increased in length to 20ft., the rubbing surface is 20 × 20, or 400 square feet; if we double the airway in length, we double the rubbing surface, and *vice versa*. This feature points out the necessity of making each airway of nearly equal length, and the "run," *i.e.* the distance the air has to travel, should be as short as possible,

(ii.) The resistance due to friction will vary as the area of section varies.

The perimeter of a circle was shewn to be 3·1416, when its diameter is 1; that of a square is 4, when its diameter is 1. The perimeter of a rectangular figure, 6ft. by 3ft., the sectional area being 3 square feet, is obviously greater than that of the square way.

We cannot use circular ways, and, therefore, square ones are the next best.

(iii.) The resistance due to friction in any airway of a given sectional area is less than the resistance due to friction in several airways of a respectively less area, but the sum of whose area is equal to the area of the single airway.

Thus, an airway, 10ft. × 10ft., the perimeter is 40ft.

Let us suppose two airways, each half the size of the large one, whose diameter is 40ft.; then we have two ways, 5ft. × 5ft., whose perimeters each equal 20ft.; their total perimeter equals 40ft., but their respective areas being half the large one, four of the areas of the small ways will equal the area of the large one. The friction will be twice the amount in the large way for the two small ones; therefore, one large airway, as before explained, is preferable to two small ones.

The friction of the air has, therefore, to be overcome by pressure on the air column, read and estimated in lbs. per square foot. This pressure, we have seen, will vary with the area, as in the case of the steam engine.

If we have two airways, one 5ft. × 4ft., the other 4ft. × 3ft., in section, the area of the first is 20ft., and the second 12ft. $\frac{12}{20}$ of the pressure required by the former will serve for the ventilation of the latter. If we treble the velocity of the air current, we treble the extent of the rubbing surface, since three volumes the amount of air pass over its surface in the same space of time that one volume did. This is the foundation of the assumption that ***the resistance increases as the square of the velocity***, and this is the law that governs friction under variable velocities.

A previous chapter shewed how to find H, the ***head of air*** necessary to produce ventilation. The head being expressed in feet, multiply the head by 0·0765lbs. (pressure of 1ft. of air at 60°F.), and divide the product by 5·2lbs. (pressure of 1in. of water), and the result is the watergauge reading.

The head (H) is a fraction (K) of the product of the rubbing

surface *(S)*, multiplied by the square of the velocity *(V)* in feet per second, divided by the sectional area *(A)* of the airway.

Then
$$H = \frac{K\,S\,V^2}{A}$$

The value of K has been determined as for a velocity of one fraction per second.

$$K = 0{\cdot}00011.$$
$$K = 0{\cdot}00033 \text{ for a mine.}$$

and ·00066 will be found more reliable in practice.

Thus, to find the resistance of an airway 7ft. × 8ft., 1000ft. long, the velocity *(V)* being 4ft. per second.

$S = 60{,}000$ square.

$a = 8 \times 7 = 56$ square feet.

Then
$$h = \frac{{\cdot}00066 \times 60{,}000 \times (4)^2}{56}$$
$$h = \frac{{\cdot}00066 \times 60{,}000 \times 16}{56}$$
$= 11{\cdot}31$ft. of pressure or
$0{\cdot}17$in. of water gauge.

The following formulæ are now all that are required to be known.

Let P = pressure per square foot.
A = sectional area in square feet.
S = rubbing surface in square feet.
V = velocity in 1000 feet per minute, as a unit of velocity.
K = co-efficient of friction.

To find total pressure

$$Pa = K\,S\,V^2$$

Rubbing surface $\quad S = \dfrac{Pa}{KV^2}$

Velocity squared $\quad V^2 = \dfrac{Pa}{KS}$

Co-efficient of friction $\quad K = \dfrac{Pa}{SV^2}$

This may be always taken as ·00066

Pressure per foot $\quad P = \dfrac{KSV^2}{a}$

Area of section $\qquad a \quad = \dfrac{KSV^2}{P.}$

To find the total pressure

$$a \times \frac{KSV^2}{a}$$

The application of these formulæ will shew the reader that *quantity per minute* and *not velocity* is the essential qualification of safe and economical ventilation; for it has been seen that the higher the velocity the greater the friction, that this increase is not in direct ratio but as the square of the velocity, and therefore to obtain this result we must *split* or divide the main air current. The following general observations on splitting the main air current may be found useful: In the first place it reduces the the velocity of the air current, and therefore the friction; but on the other hand, the increased quantity and velocity of the air in the up and downcast shafts produces increased friction, and this, if carried to excess, effectually limits the advantages which can be derived from splits. The splits can be made in a limited quantity only, or the velocity of the air current will be too feeble; on the other hand, if the splits are too few, the friction, consequent on a high velocity, will be too great. The exact mean must be determined. For air velocities the following may be taken as a reliable rule, except in very exceptional cases: 5 feet per second is the limit of safety for the velocity of any part of the air current of a mine where non-extinguishing lamps, such as Davy's or Clanny's are used; 2 feet on the other hand is too slack a current to blow away powder smoke and sweep the sides, roof and face free of gas, the average speed is 3½ feet per second. With a number of splits with an equal amount of air allotted to each, the shorter splits must be "stopped" or obstructed, artificially, to make their frictional resistance, after allowing them their proper share of air, equal to that of the largest splits, and these stoppings obviously lessen the total quantity of air in circulation. Every split should begin as near the bottom of the downcast shaft as possible, and should empty into the main return airway as near the upcast shaft as possible. In all cases regulators are to be avoided if possible, and this can be nearly always secured by making the splits of an equal length.

Stoppings or barriers should be made air-tight and strong enough not to be blown out in the event of an explosion. Two curved

brick walls, with their convex side outwards, allowing 5 feet space, which should be filled with sand, makes a good sound stopping; and, in the event of an underground fire, are fairly fire proof. In an airway of a given section it is obvious that no more air, as regards quantity, can pass through the airway, in a given unit of time, than the airway will hold, and that therefore the velocity of the air to a great extent governs its quantity, but the greater the velocity the greater will be the friction, and here lies the fundamental element of success in all colliery ventilation.

Mr. Atkinson shewed that if a mine had such shafts and airways that there were five equal splits of air, the resistance of the shafts equalled half those offered by the airways, then if the air was not split at all and the velocity was 10,000 cubic feet per minute the following was the result obtained by splitting:

No. of Currents or Splits.	Total air velocity per minute.	Quantity in each Split.
1	10000 cubic feet.	10000 cubic feet.
2	27892 „	13946 „
3	49449 „	16480 „
4	71527 „	17882 „
5	90789 „	18150 „
6	107800 „	17966 „
10	141714 „	14171 „

and the coal burnt in the upcast furnace, or in the engine driving the vacuum fan, would increase in the same proportion with the quantity of air, and the power absorbed would increase in that ratio; otherwise, if the power and coal consumed remained the same for 10 splits as for 1, we should have for one airway 10000 cubic feet of air per minute, and for 10 splits only 58556. One of the worst features in the careless laying out of a mine consists in working the pillars away too near the shafts at first starting; no room is left to make splits at a future period, without incurring some risk and great expense.

When the stoppings to be erected are situated in a road used for travelling, they must be replaced by air doors.

The position and construction of these doors is of the very greatest importance. A badly-fitting or warped door may cause explosion, and the existence of air sheets in place of doors may

allow the explosion to spread and fire the whole pit. The rules to be observed are—that every door shall remain in its proper position by being properly weighted; that if to be left open, the word OPEN should be plainly painted on both faces of the door, or, if to be left shut, the contrary. If air sheets are used, they must be made of noninflammable brattice cloth, such as Scott's, and ***not of tarred sacking.*** When naked lights are used, they should not be stuck on the sides of the air doors; the worst fire the writer ever saw in a colliery was due to this practice. If wooden doors are used, they must be thus constructed:—They should be made of oak planks, $\frac{5}{8}$in. thick, tongued to prevent leakage at the joints, and felted over the space between the door and the lintel and posts to reduce leakage. The posts should be well set back in the side of the way in brickwork, and the doors should open the way the tubs generally travel; if there is much traffic through the door, it answers to place a boy there to "trap" the door, *i.e.*, to open and close it after each train of tubs has passed, as the loss of air will shew a considerable increase of expense in the ventilating charges. It will be found useful to keep a sheet of these charges, in order to shew the cost of the air current for a given quantity of coal raised. A safety door should always be added to the ordinary doors in important places. This door consists of a door lying on the roof, and kept up by a catch; any violent explosion blows away the catch, and, in so doing, liberates the door, which falls into the position occupied by the ordinary air door; the spread of an explosion and the deadly effects of after-damp are thus guarded against, and the arrangement cannot fail to recommend itself to colliery engineers for its simplicity and cheapness. It must be continually borne in mind that in descending the pit, the miner or engineer is in a position where his life and those of his fellow men depend on his individual care, and that explosions are the certain consequences of any carelessness that is tolerated to exist as an unchecked practice, and the careless way in which air doors are left open in some collieries by miners is the most eloquent argument that they should be weighted, and a most fruitful source of danger and annoyance to the other men in the pit by the interruption of the volume of the ventilating current would be thereby avoided.

CHAPTER VI.

INSTRUMENTS USED IN VENTILATION.

THESE are the Watergauge, Barometer, Thermometer, and Anemometer:—

The principal of the watergauge is this. It is an instrument for measuring the force of the air current; by its use the loss occassioned by resistance due to friction in the air-ways, as previously shewn to take place, may be calculated.

The instrument consists of a U shaped tube of glass, and in the bend lies a small quantity of water. The air current is allowed to pass into one end of the tube, and in doing so it presses upon one column of the water, causing it to descend, until that column is balanced by the increase of head of the other column, and thus if the head of water in the latter tube be ascertained, the force of the current may be calculated.

The weight of 1 cubic inch of water is ·036lbs.

If the column of water is one inch high, the pressure will be ·036lbs. per square inch. To convert inches of height in the watergauge into lbs per square foot.

Let H = Head or difference of height in the two columns of water in the Watergauge.

P = Pressure in lbs. per square foot.

$P = H \times \cdot 4335.$

Thus if the difference of level in the two tubes of the watergauge is ·9

$$H = \cdot 9$$
$$P = \cdot 9 \times \cdot 4335$$
$$P = \cdot 39015 \text{lbs. per square foot.}$$

A simpler method is to multiply the height of the water in the column or the Head by ·036, this gives the pressure for a square inch, if this result is multiplied by 144, the result is given in lbs. per square foot. Subjoined is a table of pressures, as calculated by Mr. André, in which this latter method has been employed. Mr. Daniell considers that the watergauge is a sufficient indication of the resistance encountered by the air current in the air-ways of a Mine since the height of the gauge increases, as the length of the ways are inversely as their sectional area.

Every important air-way in a Mine must have its watergauge, and we strongly recommend that those men who have to read the gauge, should be examined from time to time on the subject.

PRESSURE OF AIR, AS SHOWN BY THE WATER GAUGE.

Height in In.	Pressure in lb. to the sq. ft.	Height in In.	Pressure in lb. to the sq. ft.	Height in In.	Pressure in lb. to the sq. ft.	Height in In.	Pressure in lb. to the sq. ft.
0·01	0·05	0·24	1·24	0·47	2·44	0·69	3·58
0·02	0·10	0·25	1·30	0·48	2·49	0·70	3·64
0·03	0·15	0·26	1·35	0·49	2·54	0·71	3·69
0·04	0·20	0·27	1·40	0·50	2·60	0·72	3·74
0·05	0·26	0·28	1·45	0·51	2·65	0·73	3·79
0·06	0·31	0·29	1·50	0·52	2·70	0·74	3·84
0·07	0·36	0·30	1·56	0·53	2·75	0·75	3·90
0·08	0·41	0·31	1·61	0·54	2·80	0·76	3·95
0·09	0·46	0·32	1·66	0·55	2·86	0·77	4·00
0·10	0·52	0·33	1·71	0·56	2·91	0·78	4·05
0·11	0·57	0·34	1·76	0·57	2·96	0·79	4·10
0·12	0·62	0·35	1·82	0·58	3·01	0·80	4·16
0·13	0·67	0·36	1·87	0·59	3·06	0·81	4·21
0·14	0·72	0·37	1·92	0·60	3·12	0·82	4·26
0·15	0·78	0·38	1·97	0·61	3·17	0·83	4·31
0·16	0·83	0·39	2·02	0·62	3·22	0·84	4·36
0·17	0·88	0·40	2·08	0·63	3·27	0·85	4·42
0·18	0·93	0·41	2·13	0·64	3·32	0·86	4·47
0·19	0·98	0·42	2·18	0.65	3·38	0·87	4·52
0·20	1·04	0·43	2·23	0·66	3·43	0·88	4·57
0·21	1·09	0·44	2.28	0·67	3·48	0·89	4·62
0·22	1·14	0·45	2·34	0·68	3·53	0·90	4·68
0·23	1·19	0·46	2·39				

ANEMOMETER.

This instrument is used to measure the velocity of the air current in feet per second, or miles per hour.

There are two forms: Biram's and Gordon's. Biram's Anemometer records its readings on a dial on the instrument; Gordon's results are recorded by means of electricity on a strip of paper. Of the two, Biram's is best suited for colliery work. The results are frequently *very* inaccurate, and the apparatus should therefore be frequently tested, since coal dust and damp increase the friction on the bearings of the fan and tend to deceive the user. The following formulæ will be found useful in correcting Anemometer readings, since they shew very clearly the rules which govern the action of a volume of air on a plane surface.

Let P = Pressure of wind in lbs. per square foot, against a surface perpendicular to the direction of the wind.

Let V = velocity in miles per hour.

$$P = \frac{V^2}{200}$$

$$V = \sqrt{200\,P}$$

When the surface is inclined at an angle e to the direction of the wind.

Let the *horizontal* pressure = Ph.

Then $Ph = P$ rin $1{\cdot}842 \cos e$.

Let the *vertical pressure, i.e.*, the pressure at 90° to the wind = Pv.

Then $Pv = P$ co-tan $e \sin e\, 1{\cdot}842 \cos e$.

Let the *normal pressure* = Pr.

That is the pressure at 90° to the surface opposed to the wind

$$Pn = \frac{Ph}{\sin e}$$

A pressure of 1lb. per square foot = 4881 grms. per square metre, so that to reduce lbs. per square foot to grms. per square metre, multiply by 4881. Subjoined is a table of pressures and velocities for general reference calculated from the above formulæ.

PRESSURES AND VELOCITIES.

Miles per hour.	lbs. per square foot.	Miles per hour.	lbs. per square foot.	Miles per hour.	lbs. per square foot.	Miles per hour.	lbs. per square foot.	Miles per hour.	lbs. per square foot.	Miles per hour.	lbs. per square foot.	Miles per hour.	lbs. per square foot.
1	·005	16	1·280	31	4·805	46	10·580	61	18·605	76	28·880	91	41·405
2	·020	17	1·445	32	5·140	47	11·045	62	19·220	77	29·645	92	42·320
3	·045	18	1·620	33	5·445	48	11·520	63	19·845	78	30·420	93	43·245
4	·080	19	1·805	34	5·780	49	12·005	64	20·480	79	31·205	94	44·180
5	·125	20	2·000	35	6·125	50	12·500	65	21·125	80	32·000	95	45·125
6	·160	21	2·205	36	6·480	51	13·005	66	21·780	81	32·805	96	46·080
7	·245	22	2·420	37	6·845	52	13·520	67	22·450	82	33·620	97	47·045
8	·320	23	2·645	38	7·220	53	14·045	68	23·120	83	34·450	98	48·020
9	·405	24	2·880	39	7·605	54	14·580	69	23·805	84	35·280	99	49·005
10	·500	25	3·125	40	8·000	55	15·125	70	24·500	85	36·125	100	50·000
11	·605	26	3·380	41	8·405	56	15·680	71	25·205	86	36·980		
12	·720	27	3·645	42	8·820	57	16·245	72	25·920	87	37·845		
13	·845	28	3·920	43	9·245	58	16·820	73	26·645	88	38·720		
14	·980	29	4·205	44	9·680	59	17·405	74	27·380	89	39·605		
15	1·125	30	4·500	45	10·125	60	18·000	75	28·125	90	40·500		

The Barometer.

The Coal Mines Regulation Act requires this instrument to be kept at the top of every pit, where dangerous gas has been found. We advise an Aneroid Barometer to be added underground, since miners can read this form of the instrument more easily, and the firing of shots will not interfere with the internal mechanism of the Barometer. If a mercurial one is used, when purchasing it, it is best to obtain its correction for capillarity from the maker. The difference of level being frequently got by means of an Aneroid, owing to the difference of readings at the two points of observation, it may not be out of place here to give the formula for arriving at the required result. The table to find the value of K may be found in Molesworth's Pocket Book of engineering formulæ, Page 13. The values given there are to be *added*.

Let R = reading in inches on Barometer at lower station.
r = do at upper ditto.
T = temperature of lower station.
t = do. of upper do.
K = correction necessary due to $T + t$,
(for this value, see table referred to.)
H = difference of level in feet between the two stations.
Then $H = 60000 (\log R - \log r) K$.
This is approximate—
To correct the reading of the Barometer for temperature.
In a Mine the value of K may be left out.

Temperature.	Correction.	Temperature.	Correction.	Temperature.	Correction.	Temperature.	Correction.
°		°		°		°	
32	0·00	47	0·05	62	0·08	77	0·12
33	0·01	48	0·05	63	0·09	78	0·12
34	0·01	49	0·05	64	0·09	79	0·13
35	0·02	50	0·05	65	0·09	80	0·13
36	0·02	51	0·06	66	0·09	81	0·13
37	0·02	52	0·06	67	0·10	82	0·13
38	0·02	53	0·06	68	0·10	83	0·14
39	0·03	54	0·06	69	0·10	84	0·14
40	0·03	55	0·07	70	0·10	85	0·14
41	0·03	56	0·07	71	0·11	86	0·14
42	0·03	57	0·07	72	0·11	87	0·15
43	0·04	58	0·07	73	0·11	88	0·15
44	0·04	59	0·08	74	0·11	89	0·15
45	0·04	60	0·08	75	0·12	90	0·15
46	0·04	61	0·08	76	0·12		

The Barometer must always be closely watched, and any difference between the readings between the bottom of the Upcast, where a Barometer should be stationed, and that at the foot of the Downcast, above that naturally due to difference of level between the two Shafts, should be the signal for a searching examination, for falls of roof or misplaced air-doors being made without unnecessary delay.

Thermometer.

It has been already shown that the head of air, or motive force of the ventilating column is due to its temperature when a furnace is in use. So many measurements are given in French or Belgian Works on Mining that I have introduced formulæ for interchanging the temperature readings in the different scales, to assist the reader.

Let F = No. of degrees Fahrenheit's Scale.
„ C = No. of „ Centigrade „
„ R = No. of „ Réamur „

$$F = \frac{9c}{5} + 32$$

$$F = \frac{9R}{4} + 32$$

$$= C + R + 32$$

$$C = \frac{5\ (F-32)}{9}$$

$$R = \frac{4\ (F-32)}{9}$$

Freezing Point = 32° F.
„ „ = 0° Centigrade and Réamur
Boiling Point = 212° F.
„ „ = 100 Cent.
„ „ = 80 Réamur.

In pits containing brassy coal, great care must be taken to keep the temperature of the air-ways as low as possible to avoid spontaneous combustion—again it will be seen that a sudden rise of temperature will cause the coal to give off a certain volume of gas due to its expansion. Gases expand nearly uniformly with an increase of their temperature, and when the volume of permanent gases remain constant, the pressure increases nearly uniformly with the increase of the temperature. For instance, according to

Regnault, let us suppose a volume of air to be represented by 1 at a temperature of 32° *F* the volume is increased to 1·36706; that of hydrogen to 1·36613, and that of carbonic acid to 1·37099. The laws that govern this important feature of gases, viz., their expansion, under an increase of temperature may be deduced from the following.

Absolute Temperature.

It has been assumed that since air expands as its temperature increases, so would it on the other hand diminish its volume if the temperature fell; thus if at 32° *F*, air as a volume of 1, it is assumed that on arriving at a temperature of 493°.2 below freezing point, 461°.2 *F* below Zero, the air would be so attenuated as to be in a state of collapse, and would possess no elasticity. This point is called *Absolute Zero*, and then the temperature of any body measured from absolute Zero, is called the *absolute temperature* of that body.

Thus if a given quantity of air at 0° *F* be raised to + 461° *F*, it is (if under a constant pressure), expended to twice its original volume; if heated to 922° *F*, its volume will be trebled.

Therefore the laws to be borne in mind are—

i. The pressure of air or any gas varies inversely as the volume when the temperature is constant.

ii. The pressure varies directly as the absolute temperature, when the volume is constant.

iii. The volume varies as the absolute temperature, when the pressure is constant.

iv. The product of the pressure and volume is proportional to the absolute temperature.

The *Absolute Zero* of the three Thermometer scales are—

Fahrenhit	461°.2
Reamur	219°.2
Centigrade	274°.00

but to avoid excessive labour in calculation, it will suffice to drop the decimal reading. Gas compounded of carbon and hydrogen occasionally throws out oily products, which will interfere with the action of these laws.

It will be seen, therefore, that violent changes of temperature in ventilation are to be avoided in working fiery and brassy mines, or gas will be liberated that otherwise would have remained in the seam.

CHAPTER VII.

General Observations with regard to Ventilation in Practice.

Ventilation in theory will be found a comparatively easy matter; in practice, however, falls of roof and the carelessness of the miners will be found a source of endless annoyance and anxiety. A miner is bound by laws (Sec. 55 Coal Mines Regulation Act) to report instantly to the fireman should he discover anything wrong with the ventilating current, or the state of the roof or mine generally, such as leads him to suspect danger to himself or his fellow workmen. This is not always done, as the Act requires, *instantly*, and the duty of every manager is plain where this is the case; the Act having been broken, the miner should be punished under the Act. Such very strong assertions are made concerning the management of collieries by men, whose very assertions shew their ignorance of the subject, and since such assertions, being those of uneducated men, are always directed more or less against the capitalist or employer of labour because he is an employer of labour, that we strongly recommend managers to adopt two practices, viz., to summon *all offenders* before the magistrates, and to register the conviction in a book kept for the purpose; for it will be seen at a glance that in the present day none but very experienced viewers are acting wisely if they take upon themselves the office of weighing the culpability of the offender. A reference to the various mining Acts will shew that wilfully damaging ventilating machinery is expressly provided for. It is not the wilful damage but the damage and danger incurred *by carelessness* that the manager will have to provide against.

The position of all important air doors in a mine may be electrically determined by a piece of apparatus designed by the writer for the purpose, which costs but a trifling amount; but the "trapper" system, by placing boys to watch the doors, is perhaps better, only it will frequently be found necessary to place men to watch the boys.

The most important posts in the ventilation department of a colliery are the fireman, roadsman, trapper or doorkeeper, and master wasteman.

The fireman's duties are very hazardous. He is a *competent person solely employed to test the pit for gas.* When inflammable gas has been found (and we presume that all viewers will see the propriety of examining before each shift begins work, even where it has not been found), he has to examine the pit once in every shift or once in every 24 hours; should he find gas, he must report the same in a book kept for the purpose. The Act should have made him post a notice at the pit head, containing extracts from the book, shewing briefly where gas had been found throughout the mine. He also places "fire boards," or notices of dangerous gas, at the entrance to headings which have been found in his examination to contain it. These boards should be painted red and made easily recognisable to miners who cannot read. Another most responsible duty of the fireman is to act as the "competent person" where shots are being fired. No shots should be fired where naked lights are used in the vicinity, as a large volume of gas may exude or be discharged after the shot, and so become ignited, although the ventilation may be ample, neither should lamps on Davy's principle be used for the operation, but self-extinguishing lamps, such as Stephenson's or Williamson's safety lamps. The fireman should make his inspection immediately before the entrance of the workmen to the mine, *and allow no delay to occur*, as a large volume of gas may be easily discharged in the interval elapsing between his inspection and their commencing work, which may result in an accident. He should take notice of any loose hay or straw lying about in the pit, and report on any horse dung or rubbish left lying about on the roadways; if brassy lumps of coal are thrown out on the road, they should be got rid of. These are all apt to generate, gob-fire by spontaneous combustion, and although such combustion may not be sufficiently active to cause flame, nevertheless it must be remembered that all combustion detracts from the purity of the air, by depriving it, as already shewn, of a portion of its oxygen, and by increasing the temperature of the air it tends to facilitate the escape of noxious gases.

The roadsman's duties principally consist in the maintenance of all the airways in a good and secure condition. His especially duty is to

provide against falls, and should these falls occur he must exercise *great care*, both in approaching the spot after the fall, and in providing against a further fall. On no account must he ever work with a naked light, and it will be found advisable to give him a practical training as a fireman before he becomes a roadsman. This is easily done by sending him round the pit with the fireman for a time, so that he may become conversant with the nature and behaviour of the fire-damp, and the necessary precautions to be taken in testing for its presence with the lamp. Possibly at a future date when the mania for education has been diluted with a little common sense, the school boards in mining districts may see the propriety of teaching the pit boys the nature and behaviour of fire-damp, &c., but in the mean time the manager must do it.

The Overman is responsible (subject to the control and supervision of the manager), that adequate ventilation is supplied to all parts of the pit, and these three officials, viz., the overman, fireman and roadsman should be selected from the others, on account of their qualifications to fill these respective posts, and not on account of their long service or good conduct; the posts are too responsible for this latter cause of selection, which is only applicable where no responsibility exists, and not where the person to be promoted is incapable of accepting that responsibility.

Falls of roof can only be provided against by timbering of suitable strength and quality; this cannot well be entered into here, as the nature of the roofs of no two pits are alike. It will be found advantageous to study the methods of timbering and walling, in use in the district under the various conditions of working, and to apply that system which appears to meet your own case best.

A practice used to exist of so splitting the main air current, that in the first case the greater part of the air circulated round the pit, visiting district after district, thereby becoming more impure and explosive as it went on, and in the 2nd case, the splits were so badly arranged that some districts were never really ventilated at all.

The master wasteman is a most responsible person, and the waste, or old workings, is a very fruitful source of gob fire, the cause of which we will here explain and shew how it may be provided against.

"Brassy coal" as it is technically called, is coal containing a certain per centage of iron pyrites. This pyrites is the yellow spots we have on house coal. Its chemical formula is $Fe\ S_2$. It is therefore sulphide of iron and merely requires one more atom of oxygen, to allow the sulphide to become converted into a sulphate with the evolution of a considerable quantity of heat. If coal becomes exposed to a moist hot atmosphere, or if air is blown *through* the coal instead of over the *surface* of the coal, the cooling effect is partially destroyed and the heat evolved by the oxidation of the pyrites is sufficient to fire the seam. In waste workings this frequently takes place, and the following rules must be observed. No slack coal or waste heaps must be allowed to accumulate, neither must the practice of "Putting back" the small coal be permitted. The air circulating in the waste workings must be a brisk dry current, or the waste had better be "Stopped off" altogether, but in no places where pillars have been removed must the air be allowed to stagnate; if these precautions are taken gob fire will be guarded against as far as human foresight can guard against such contingencies.

This is the master wasteman's province, and he should have frequent interviews with the manager and discuss the state of the ventilation from day to day in such wastes, but as a fixed rule it is advisable always to ***stop off all goafs and wastes by air-tight fire proof brick stoppings***, as described in a previous chapter.

Considerable attention having been paid to the employment of air by means of compression, that we may briefly insert the laws affecting its use here. From experience obtained at the Ronchamp Collieries, it has been deduced that the resistance is directly as the length of the conducting pipe; it is directly as the square of the velocity of the flow, and inversely as the diameter of the pipe. The point to be noticed is that for velocities ***under four feet per second*** the loss by transmission is not very great, but with higher velocities it rapidly becomes an insurmountable obstacle.

The following formula will be of use in the above question:—

Let A be the area of the pipe in square feet.

S = the perimeter multiplied by the length of the pipe in feet.

V = the velocity of the air in feet per second.

h = the head or height of the motive column in feet, the pressure due to which must be substracted from that in the reservoir, to find the pressure at the end of the air pipe.

Then

$$h = \frac{f S V^2}{a}$$

Taking the value of f at $\frac{1}{4}$ of the friction in the air-ways of a Mine.

Another system of ventilation, by means of jets of steam or air has been tried, but is a very wasteful system except under peculiar circumstances. Where a hauling engine is situated directly at the bottom of the shaft, the exhaust steam may be utilized, and it is only under such circumstances as these that it can be employed as a blast to cause a circulation of air. The following formula will be found useful :—

Let S = Section of pump.
O = Sectional area of orifice (air hole.)
P = Weight of 1 cubic yard of air in reservoir.
V = Piston speed of supply pump to reservoir.
H = Tension of air, V velocity of escape.

Then the work to be done by the piston during the introduction of air into the reservoir, exclusive of the work done in compressing the air from the ordinary atmospheric pressure (15lbs. per square inch), to the constant pressure at which it enters the reservoir will be

$$S\,p\,H\,v = S\,p\,H\,v\,\tfrac{o}{s}.$$
$$= p\,H\,V\,s.$$
$$\therefore\ V = V\,\tfrac{o}{s}.$$

$V\,o$ is the volume of air escaping per second, $V\,o\,p$ is the weight p of the air, then the expression of the work to be done in introducing the air into the reservoir will be

$$P\,H = \frac{P\,V^2}{2}$$

It has been calculated that the vis viva of a jet of air under a compression of 5 atmospheres only represents $\frac{6392}{12851}$ of the force necessary to compress it. This loss may be diminished by lowering the degree of compression in tension.

The following are the elements of success in using blasts as a means of ventilation, and are the results of experiences in the

experiments of Nozo and Geoffroy. The blast pipe should be seven times longer than its diameter ; the distance of the mouth of the tuyère, from the point of entrance to the blast pipe should not exceed three times the diameter of the blast pipe, and the tuyère should not penetrate to a greater extent than twice the diameter of the blast pipe. It is immaterial to the effect produced whether the position of the blast pipe be vertical or horizontal. Practical experience shows that the useful effect obtained by ventilating with a steam blast, is only from 5 to 6 per cent. of the useful effect produced by a machine absorbing the same amount of steam.

To utilize a jet of air to ventilate a mine, the best effect will be secured by placing the delivery or blow pipe in the centre of the axis of the shaft. It is obvious that the inertia, that the compressed air possesses, is spent in opposing the resistance of the column of air in the shaft, and in to a small degree communicating a portion of its inertia to that column, consequently the *velocity* of the air in this case is of considerable importance. In fact, the power required to compress the air to effect the blow at the necessary velocity is greater than the force required to impart that velocity by means of a Guibal Fan, and this should be sufficient reason against the use of air or steam blast, as a means of ventilation for a Mine.

When steam at high pressure impinges against a column of air of a different temperature, a considerable portion of the useful effect of that steam must be lost by reason of the unavoidable condensation that take place, and the increase of temperature that this condensed steam is able to impart to the air column in the shaft, had it remained at its original pressure, is lost by its condensation, so that the atmosphere of the shaft in which the blast is fixed and delivered is in one place nothing more than a mixture of air and steam of a nearly uniform temperature, and it is for the engineer to determine the precise spot in the shaft, at which this state of things is brought about ; if at any depth in the shaft, good ventilation cannot take place.

The general conclusion arrived at, are as follows :—

Blasts of air as a means of ventilation, in Collieries, may be dismissed from our consideration as impracticable.

Furnaces and steam jets must not be used, except when such advantageous circumstances as we have pointed out, permit their economical use.

Mechanical Ventilation by means of fans, which do not shut off the communication between the surface atmosphere and that of the Mine when the fan is not in motion, and whether a direct acting Blowing Fan, or a Centrifugal Fan, are not a satisfactory system of ventilation, on account of the great speed at which they must be rotated. Of this class, Guibal's Fan when properly erected, is the least objectionable, and may fairly be regarded as an economical and convenient method of ventilating a pit; Lemielle's Air Pump system is an expensive and easily deranged system, and on the whole we can safely recommend Guibal's Fan as being the best means of mechanical ventilation, although from an engineering point of view, it cannot be considered perfect.

CHAPTER VIII.

Subjoined is an abstract of the duties, as set forth by Act of Parliament, of those persons who are responsible for the ventilation of the mine.

Reports, where danger exists, cannot be made too promptly, and it is the duty of every man in the pit to cause no danger to himself or others, and when danger exists, such as a fall of roof or a blower of gas, he should not delay to report the same at once, and should place a warning at the spot, or station someone to caution persons from inadvertently entering the spot where the blower or fall is.

1.—An adequate amount of ventilation shall be constantly produced in every mine to dilute and render harmless noxious gases, to such an extent that the working places of the shafts, levels, stables, and workings of such mine, and the travelling roads to and from such working places, shall be in a fit state for working and passing therein.

2.—During the twelve months following the discovery of inflammable gas in a mine, a competent person shall, before the time for commencing work in any part, inspect with a safety lamp

that part of the mine and the roadways leading thereto. The inspection shall be made once in every twenty-four hours, if one shift is employed, and once in every twelve hours if two shifts are employed; and a report of the state of the ventilation shall be recorded in a book kept at the mine for that purpose, and signed by the person making the same. In a mine in which inflammable gas has not been discovered during the preceding twelve months, the inspection shall be made once in every twenty-four hours.

3.—Whenever the mine, or any part thereof, is discovered to be dangerous by reason of gases prevailing therein, or of any other cause, every workman shall be withdrawn from the mine or part thereof, and they shall not be readmitted until the mine or part thereof has been inspected by a competent person, and reported by him to be safe.

4.—In every working approaching any place where there is likely to be an accumulation of explosive gas, no lamp or light other than a locked safety lamp shall be used, and whenever safety lamps are required, a competent person shall examine every safety lamp immediately before it is taken into the workings for use, and ascertain if it be secure and securely locked, and in the said part of a mine a person shall not, unless he is appointed for the purpose, have in his possession any key or contrivance for opening the lock of any such safety lamp, or any lucifer match or apparatus of any kind for striking a light.

Overman.

Subject to the control and supervision of the manager, the whole operative details shall be under the care and charge of the overman. The overman shall see that the workmen of every class, in their several departments, discharge their duties; and shall receive and attend to all reports made to him as to the state of repair of the air courses, machinery, mid-wall trap doors, roads, cubes, and working places. He shall cause remedies to be provided where needed, and shall see the general and special rules faithfully and vigourously enforced, and he shall have power to hire and discharge workmen.

He shall have under his immediate and special charge, the shaft, slides, pump, and relative fittings, all of which he shall keep safe and efficient.

He shall attend to the ventilation, in terms of rule No. 1; and to the observance of other general rules, as far as these, from their

nature, can be observed by himself, or fail to be observed by others under his charge.

He shall perform the special duties as to the examination of machinery and others.

He shall see that a plentiful supply of timber for props and other purposes, required by workmen to carry on their operations with safety to themselves, is always ready; and shall cause the same to be cut in proper lengths, and laid down in the working places.

He shall, without delay, report to the manager, or agent, or owner, any matter or thing coming under his notice, necessary to be observed or carried out, with a view to compliance with the general or special rules, which he cannot perform.

Furnacemen.

Subject to the control of the manager or overman, the furnaceman shall act under, and obey the directions of the engineman.

Roadsmen.

The roadsmen in their different divisions and shifts if more than one, shall, at least daily, make careful inspection of the whole roadways and working places, from the pit-bottom throughout the mine, and shall keep the same free from all obstructions, and of the fixed height and width, necessary for proper passage and for ventilation. They shall repair and remedy all damages and defects in the roads of the mine, and shall examine and put, and keep in proper condition, all trap doors and see the regulations enforced that the same are kept closed, and whenever practicable should endeavour to make and keep such trap doors self-acting. They shall make and place sufficient trap doors whenever the progress of the operations of the mine shall render these necessary.

They shall stop the passage of men and materials, through or under defective roads, roofs, or places, until the necessary repairs shall have been executed. They shall receive information concerning any interruption in the ventilation or any other cause of danger and shall communicate with the manager or overman immediately, and shall aid and assist in the rectification and remedy of the same, and shall, when so employed, be permitted to use only safety lamps in mines where inflammable gas has been found within the preceding twelve months. All lighted or combustible substances are forbidden to be used in the course of such operations.

The roadsman shall report to the manager or overman any instances of neglect on the part of miners, in not carrying forward their faces or walls, in accordance with the plan pursued in working the Mine. They shall also examine and report to the manager or overman, instances of neglect, and acts of carelessness on the part of the miners or brushers, in failing to remove, or in not removing with proper caution, the strata necessary to be removed to form roads, or in not carrying forward the brushing with sufficient regularity, and of the proper dimensions, or with leaving the brushing with loose or hanging stones in and about the strata "brushed."

As removing falls from the roofs of roads and air-courses, and repairing defects therein, are within the roadsman's duties, and as they are charged with the maintenance of all roads and passages in the Mine, they are enjoined to proceed with the greatest caution—both for their own safety and the successful execution of their duties. In these operations they must therefore be careful, and are required to prevent all other workmen coming near any defective places, or interfering with them when at work. They are required to undertake no repair of unusual magnitude or danger, without sufficient assistance, and until provided with every necessary material, which will be supplied on application to the manager or overman.

Without prejudice to the foregoing directions, it will be the special duty of the roadsman to observe the matters embraced in the following general rules :—

1. Upon discovering that any part of the Mine is dangerous to withdraw therefrom any workmen therein employed (which workmen shall be subject to the roadsman's orders, to that effect), and report the state of matters to the manager, overman, or fireman.

2. To report to the manager or overman, where they observe any violation of the rule as to the use of gunpowder.

3. To see that every man-hole, or place of refuge, is kept clear.

4. To examine the roof and sides of every travelling road at least daily, and see that the roof and sides are safe.

5. To report any damage to any fence, casing, lining, means of signalling, or otherwise, that may be observed.

Firemen.

If inflammable gas has been found in the Mine within the preceding twelve months — which it shall be the duty of the manager to ascertain and intimate to the fireman—then it shall be the duty of such fireman, or firemen, if more than one, in their respective positions or shifts, to perform the duties of examining and inspecting, with a safety lamp, the Mine and roadways, and making the report thereon in terms of Rule No. 2.

If the fireman shall encounter falls from the roof in any of the roads which he requires to traverse, or in working places under the care of the miners, he shall not proceed further in the direction of such falls, so as to pass under the broken roof, but shall endeavour cautiously, to ascertain if there be any accumulation of fire-damp or other impurity in, about, or beyond the falls, so that the safest way of clearing the same may be learned, and he shall proceed elsewhere through the Mine to examine the unobstructive parts thereof, and to complete his inspection; whereupon the fireman shall report to the manager or overman the state of the falls, and whether free from impurity, to the end the necessary directions may be given for having the same cleared away, and the roof secured, and until this shall be done, no miner or workman shall be at liberty to proceed near, or be under the broken roof unless employed in remedying the same.

Door Keeper (trapper.)

Every person employed in keeping a trap door, for the production or promotion of ventilation in the Mine, shall during his shift, remain continually at the post assigned him, and carefully observe the directions he receives from the manager, overman, roadsman, or fireman, as to the opening and shutting of such doors, either on the occasion of other workmen passing through the same, or at the beginning or end of the shift.

Coal-Dust and Safety Lamps.

By the kindness of Mr. Galloway, I make here some extracts from his paper, "On the influence of Coal-dust in Colliery Explosions," read before the Royal Society. On this important subject, Mr. Galloway says—"In all dry Mines the coal-dust lying on the floor of the roadways rises in clouds and fills the air

when it is disturbed by the passage of men, horses, small waggons, &c., a sudden puff of air, therefore, such as that produced by a local explosion of fire-damp, or by a shot blowing out its tamping, must necessarily produce the same effect in a greater or less degree according to its intensity. The mixture of coal-dust and air, formed by the action of either the fire-damp explosion or the blown out shot, will be inflammable if it contain any larger proportion of fire-damp than 0·892 per cent., and the flame of the original explosion will pass on through it, extending the area of the disturbance as far as the same conditions exist, or, it may be, to the utmost limits of the workings. If it contain more than 0·892 per cent. of fire-damp, it will be more and more explosive, according as the proportion of fire-damp is greater, until a maximum point is reached, beyond which its explosiveness will begin again to decline. If, lastly, it contain less than 0·892 per cent. of fire-damp, or even if it consist only of coal-dust and pure air, it will still be so nearly inflammable that it will probably become so when it undergoes the compression and consequent heating, which the occurrence of an explosion in one part of a confined space must necessarily produce throughout the remainder of the same space. It is probable, moreover, that some kinds of coal-dust require less fire-damp than others to render their mixture with air inflammable; and it is conceivable that still other kinds may form inflammable mixtures with pure air."

"I may mention that in the apparatus which I have hitherto employed, the proportion of coal-dust which gave the best results was much larger than might at first sight be thought necessary, namely, about one ounce of dust to a cubic foot of air for all mixtures of gas and air, ranging between one of gas and forty of air. Also, in one of the experiments with the return air of a Mine, the air requires to be literally *black with dust* before it will ignite. It is therefore obvious, that the particles which are floating about in the air of a dry Mine, in its normal state, cannot render it inflammable; and it is probable that only the sweeping action of a gust of wind, like a squall, passing along the galleries, can raise a sufficient quantity to do so."

"Some of the colliery explosions which have occurred during the last two years are amongst the most disastrous on record, and the attempts that have been made to explain them are of the usual unsatisfactory character. The assumption, without a

vestige of proof that fire-damp has suddenly burst from the strata, is still maintained even in cases in which the flame is seen to have ramified into the extremity of every *cul-de-sac* and extended to the opposite boundaries of the workings. The very token whereby the ubiquity of the flame is made manifest, is the so-called *charring* of the timber, coal, and rubbish : and this, generally in the case of the timber, and always in the case of the coal and rubbish, consists of a coating of a coked coal-dust adhering to them superficially, and testifiying unmistakably by its presence that coal-dust has actually been playing the part which is claimed for it by myself and others."

When smoke and soot are produced ; or dust is ejected from the shafts ; or the coal, stone, and timber have a charred appearance, due to a deposit of coked coal-dust on their surface ; or, lastly, when a large superficies of the sides of the galleries are found to be on fire immediately after the event, we may safely conclude that coal-dust has played an important, if not a predominant, part in the explosion. The manner in which coal-dust operates in setting fire to coal and timber is probably as follows :— The air is travelling rapidly in one direction along a gallery, throwing a continuous shower of dust, small pieces of coal, and, against all surfaces that deflect it or obstruct its course ; at the instant the flame traverses it, however, the coal-dust is melted, it then assumes the properties of flaming pitch, adheres to the surfaces against which it is thrown, and rapidly accumulates until it forms a crust of greater or less thickness, according to the length of time the air continues to travel in the same direction. If it is thick enough to retain its high temperature, and is supplied with fresh air immediately, it continues to burn, and the flame soon communicates itself to the body of the coal or timber ; but if it is thin, or if the surrounding atmosphere cannot support combustion, it becomes extinguished. In the second case, the surface covered with the crust or layer of coke is vulgarly said to be *charred*."

"The dangers due to the presence of coal-dust in dry Mines can be very easily avoided by sprinkling water plentifully on the principal roadways along which the air currents pass, in going to, and coming from the working places. For example, Llwynypia Colliery, which was formerly one of the driest and most dusty Mines in the South Wales basin, is now kept constantly damp, or wet, in this way with a daily expenditure of about 1,800 gallons

of water. The amount of air passing through it at present is over 80,000 cubic feet per minute, and its out-put of coal is, on the average, about 800 tons per day."

The above extract from the paper will enable the reader to estimate the necessity of keeping the ways damp.

Another very important feature in the safe working of a colliery is the type of safety lamp employed. In a paper read by me before the Institution of Mechanical Engineers, on April 25, 1879, on the construction and comparative merits of the safety lamps generally in use in England, the reader will find the subject fully treated and the actiou of the combustion chamber, and chimney in each lamp illustrated by means of diagrams. Lamps should be self extinguishing, *i.e.* they should become extinguished when immersed in an atmosphere of fire-damp; Davy's and Clanny's lamp do not possess this property, and are, therefore in the opinion of many, unsafe in fiery pits. Stephenson's and Williamson's are perfectly safe; Mueseler's lamp is stated to become extinguished like the two former lamps, but this is incorrect, for I have obtained nine explosions with it out of twelve trials, at 26 feet per second, and numerous other instances of its uncertain behaviour have come to my knowledge, from most unquestionable sources.

The "Protector" lamp, in our opinion, is no safer than Davy's lamp. On no account must mineral oil be burut in safety lamps, unless the pit is very free of gas. Subjoined is a table of experiments with safety lamps.

EXPERIMENTS MADE WITH SAFETY LAMPS.

No. of Experiment.		Description of Lamp.	Velocity of Air per Second.	Length of Time for each Experiment.	Result of each Experiment.
No. 1 Experiment.	1	Davy	8 Feet	20 Seconds	Exploded
	2	Clanny	do.	120 ,,	No Explosion
	3	Mueseler	do.	56 ,,	Extinguished
	4	Stephenson	do.	8 ,,	do.
	5	Williamson	do.	9 ,,	do.
No. 2 Experiment.	6	Davy	10 Feet	16 Seconds	Exploded
	7	Clanny	do.	65 ,,	do.
	8	Mueseler	do.	14 ,,	do.
	9	Stephenson	do.	1 ,,	Extinguished
	10	Williamson	do.	1 ,,	do.
No. 3 Experiment.	11	Davy	16 Feet	8 Seconds	Exploded
	12	Clanny	do.	24 ,,	do.
	13	Mueseler	do.	4 ,,	Extinguished
	14	Stephenson	do.	1 ,,	do.
	15	Williamson	do.	1 ,,	do.
No. 4 Experiment.	16	Davy	20 Feet	10 Seconds	Exploded
	17	Clanny	do.	9 ,,	do.
	18	Mueseler	do.	11 ,,	do.
	19	Stephenson	do.	1 ,,	Extinguished
	20	Williamson	do.	3 ,,	do.
No. 5 Experiment.	21	Davy	25 Feet	5 Seconds	Exploded
	22	Clanny	do.	61 ,,	do.
	23	Mueseler	do.	5 ,,	Extinguished
	24	Stephenson	do.	4 ,,	do.
	25	Williamson	do.	4 ,,	do.
No. 6 Experiment.	26	Davy	30 Feet	6 Seconds	Exploded
	27	Clanny	do.	10 ,,	do.
	28	Mueseler	do.	6 ,,	do.
	29	Stephenson	do.	2 ,,	Extinguished
	30	Williamson	do.	1 ,,	do.
No. 7 Experiment.	31	Davy	16 Feet	13 Seconds	Exploded
	32	Clanny	do.	7 ,,	do.
	33	Mueseler	do.	2 ,,	Extinguished
	34	Stephenson	do.	25 ,,	do.
	35	Williamson	do.	15 ,,	do.

REMARKS.—An apparatus was attached to one of the Separation Doors, connected with the Fan, and the velocity of air was got by the Anemometer. Coal gas was used in making the experiments.

A few practical hints may be added as to how to estimate the per-centage of air in combination with fire damp with the lamp, when looking for gas. It is a known fact that if fire damp contains an excess of bi-carburetted hydrogen, a red-hot wire will fire it; again, the force of an explosion of fire damp will be directly proportional to the amount of oxygen it contains to ensure combustion. One cubic foot of gas to five and half cubic feet of air is the most feeble combination, the gas if ignited, merely "flashes." The maximum effect is reached at 1 of gas to 10 volumes of the air; this point is shewn by a blue "cap" or halo round the top of the flame. If a Davy or Clanny lamp is ever immersed, the flame instantly begins to mount the inner gauze after the "cap" has made its appearance. To observe the "cap," the direct rays from the light must be shielded from the eyes, and this is best done by observing the top of the flame between the two fingers. Fall of roof, faults, and all abandoned workings must be approached with care; the existence of a blower should never be searched for with any but an extinguishing lamp on Stephenson's principle. The sump should be carefully tried for gas occasionally, if it contains any gas, a slight rise in the water level will make the gas blow through the covering, and, since the cager generally works with a naked light an avoidable source of danger is incurred, and a watch must therefore be kept on it. When working a very fiery seam, the rate of progress must be sufficiently slow to allow the gas to drain off quietly. In conclusion, the *only* system by which a fiery mine can be worked safely is by paying strict attention to what appear, at first sight, to be minor details. The fire-triers must be picked men, and those men who are connected with the ventilation department must be practically acquainted with their duties. We recommend every viewer to examine the general effect of the main air-current periodically. He should ascertain how much air, at what velocity, is required, according to the rules we have here given, and his duty is to see that (i) the amount of air passing into the workings is *adequate.* (ii) That the adequate quantity does really pass through the pit.

No instructions to subordinates will avail, unless the Chief Engineer satisfies himself that the instructions are necessary, and if so, that they are carried out in the spirit with which they were issued. The ventilation of a colliery is a most responsible duty, and since the laws that govern the velocity and

quantity of the air current are now understood, the responsibility is reduced to a minimum, but if neglected, explosion is the certain result. More explosions have occurred through neglect to ascertain what the effect of splitting or stopping would be *before doing it* than through insufficient ventilation. A prevalent idea amongst roadsmen is that if a large quantity of air passes down the shaft, the pit is well ventilated, this entirely depends on the disposition of the air current in the pit, and further, if the shafts are calculated to yield a passage to a given volume of air, and the requirements of the Mine are such that that volume is absolutely necessary, the shaft must not be blocked up with guides, signal wires, pump rods, &c., after the calculation is made.

Blowers of Gas.

There are many seams of coal that do not emit carburetted hydrogen steadily in a regular flow, but in outbursts. It has been generally admitted that atmospheric pressure is directly concerned in such "blowers," as they are technically called, but some eminent mining authorities maintain that a low reading of the barometer does not necessarily induce a blower of gas. I think that when we consider that atmospheric pressure is generally represented by a pressure of 15lbs. per square inch with ordinary barometrical readings, and since we find blowers of gas exuding from a seam with a greater pressure than 15lbs. per square inch, we may readily assume that although atmospheric pressure is directly concerned in partially determining the amount of gas exuding slowly from the face of the coal, yet we must not imagine that because the barometer is high we are safe from a blower of gas. There are three ways in which a blower may be formed. The first is by a sudden rise of temperature expanding a body of gas confined within the seam; this cause generally brings about a feeder, or thin stream of gas exuding from the seam at a low pressure. The second cause we may assume to be due to heavy falls or subsidences of the accompanying strata, both above and below the seam in which the blower makes its appearance. The third cause may be ascribed to the displacing action of large bodies of water entering cavities filled with gas. In these latter

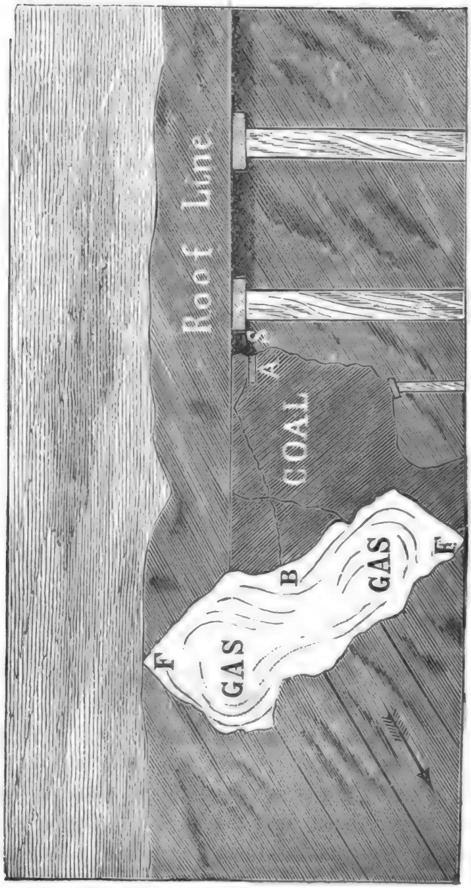
cases the pressure will be directly as the weight of a column of water of the height, from roof to floor, of the cavity filled, and will be exerted equally in all directions.

Newly opened seams are always more or less liable to small blowers; in fact, in many sinking operations, one of the first indications of the existence of the coal measures is found in bubbles of carburetted hydrogen ascending through the water in the shaft, and when such indications present themselves a centrifugal fan must be placed at the top of the shaft, and the air conveyed in canvas pipes to the bottom of the shaft to dilute the gas, and all naked lights prohibited.

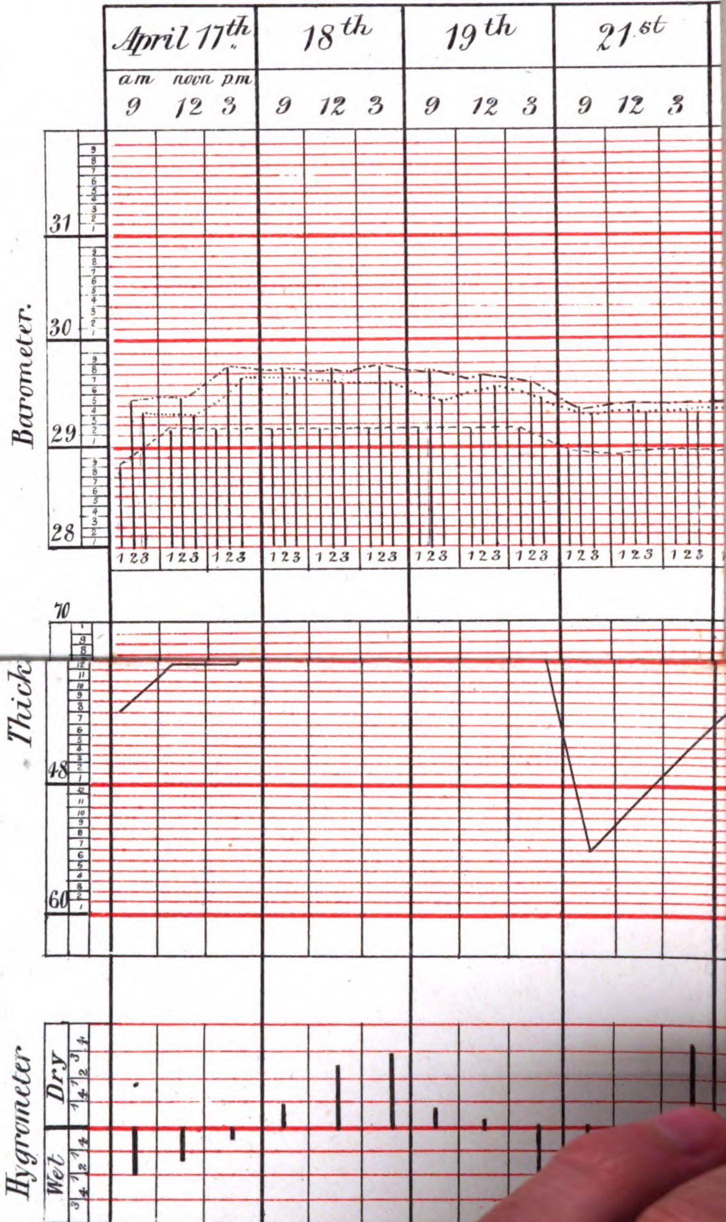
A fault, especially a down throw, is a very likely place to expect a blower, and when approaching a fault, bore-holes should be drilled 10 feet in advance of the work.

In dealing with a blower of large dimensions the following must be borne in mind:—It is *absolutely essential* that the volume, or quantity in cubic feet per minute, of the air split allotted to the particular district in which the blower exists should be so materially increased as to permit of the prompt dilution of the gas given off, and that when possible, the product or combination of air and fire damp should not be allowed to circulate in the mine, but should be conveyed in pipes directly up the upcast shaft. The gas should be encouraged by artificial means to exude; of these the simplest is obtained by driving pipes into the face or fault. The quantity of gas delivered by the blower per minute must be calculated, and the *diluting capacity* or quantity of air per minute yielded by the air split must be proportioned, as denoted in the chapter on chemical interference with the main air current, to dilute the gas. In that chapter we shewed that 15 cubic feet of air will render 1 cubic foot of gas not explosive, that for further precautions the 15 cubic feet of air absolutely necessary should be increased to 100 cubic feet; then for every cubic foot of gas yielded of the blower, 100 cubic feet of air will be required over and above that afforded, under the ordinary circumstances, by the air-way. The air doors and regulators governing the splits, must therefore be so arranged as to ensure that amount of air being admitted. In no case must any but self extinguishing lamps be used in the vicinity of the blower, when, the precaution we have stated having been duly taken, the blower is reduced to a harmless evolution of gas, and may be allowed to continue as a

means of draining the seam. Cavities filled with gas are the most dangerous enemy of the engineer; their existence cannot be foreseen, and their presence is too often demonstrated by a violent explosion after a shot has been fired. The accompanying plate shews how easily one of these cavities may be fired, but it must be borne in mind that pure gas will not become ignited, except when its combustion is maintained by the flame being surrounded with fresh air; were it not so, on lighting the gas in an ordinary dwelling house, the flame would travel back along the gas main till it communicated with the gas meter, which would explode, or rather become ignited.



The shot hole S has a fissure $A.B.$ communicating with a body of gas enclosed in the cavity, showing where the seam is broken, prior to the dip shewn by the arrow on the deep side of the fault $F.F.F.$ On firing the shot the flame ignites the gas in the cavity and an explosion follows. If the holing had been preceded by a bore hole the cavity would have been discovered. McKean's or Jordan's hand rock drill is eminently suited for such operations. If the fissure $A.B.$ contained only pure gas, the flame would become extinguished for want of pure oxygen to maintain its combustion and no explosion would follow. Large quantities of water in the pump or drainage of the Mine should be avoided, as the pressure of the water due to its height in the sump hole is exerted, according to a well known law in Hydrostatics, ***equally in all directions***, and it will be at once seen that if a blower of gas is blowing in the water in the sump, this pressure will be exerted on the face of the blower, and if greater than the blowing pressure of the gas, the stronger pressure of the water will overcome the weaker pressure of the gas and make it blow off elsewhere, very probably in the Mine ; in like manner violent fluctuation of the water level in the pump are to be avoided as tending to produce similiar results. When coal mines are worked by means of an incline plane, commonly called a "jinney-way" or engine-way, with a hauling rope, and the extent of the workings is not too extensive, a simple and economical method of ventilation will be secured by making the hauling rope revolve a vacuum fan at the mouth of the adit when the tubs are running, or if the pit contains water in any adequate quantity, and a suitable fall can be secured of not less than six feet, a turbine may be set in motion by the waste water, and the rotation of its shaft employed to drive the fan.



April 17th
18th
19th
21st
am noon pm
9 12 3
Barometer.
31
30
29
28
70
Thick
48
60
Hygrometer
Wet
Dry

Explanation of the Gas Chart.

The object of this chart is, firstly, to shew the method to be employed in making observations on blowers or feeders of gas in a fiery mine, when danger may be apprehended; and secondly, to illustrate the effect of changes of temperature, and pressure in the volume of the gas. The thickness of the gas was obtained by erecting a 60-inch staff, graduated in inches, and placed where the gas shewed itself; the fire trier slowly raised his lamp until the "cap" showed on its flame, when the level of the flame, read off on the staff, gave the equivalent level of the gas. The observations were taken three times a day, viz., at 9 a.m., 12 noon, and 3 p.m., the pit being running, on the 23rd. On the greatest thickness of gas was 4ft. 9in. in the 5-ft. heading, leaving only 3 inches of air on the bottom of the roadway. The atmospheric condition in the pit was shewn by the instruments to be dry, 4° Fah. in point of temperature above the surface temperature, and higher than the normal temperature of the pit, rising towards noon, whilst the atmospheric pressure was on the surface 28·9 inches, equal to a pressure per square inch of 14lbs. 7⅕oz., and in the pit 29·3 inches, equivalent to a pressure of 14lbs. 10⅖oz. per square inch (being a difficiency of pressure per square inch of rather more than three ounces avoirdupois from the normal atmospheric reading of 15lbs. per square inch on a barometer reading of 30 inches.)

On the other hand, the minimum thickness of gas was on the 18th of April at 12 noon, when it was only 1ft. 7in. in the 5-ft. heading, the surface temperature being 42° Fah., and that in the workings 58°; the barometer reading in the workings being 29·6 inches, or 14lbs. 3⅕oz. per square inch, and on the surface 29·1 inches, or a pressure per square inch of 14lbs. 2⅘oz. In the chart, No. 1 barometer was situated on the surface, No. 2 barometer in the pit bottom, No. 3 in the workings. The thermometers are thus shown, No. 1 thermometer was on the surface, No. 2 in the pit bottom, No. 3 was 618 yards in-bye, No. 4, 1,236 yards in-bye, No. 5 in the workings. The condensed results of the observations when tabulated are as follow:—

Date. 1879.	Temperature. In workings.	Temperature. On surface.	Atmospheric pressure per square inch. In pit.	Atmospheric pressure per square inch. On surface.	Hygrometer showed pit to be	Thickness of gas in 5-foot heading.
	°	°	lbs. oz.	lbs. oz.		ft. in.
April 17	57	41	14 12	14 $8\frac{4}{5}$	wet	3 1
,, 18	58	42	14 $14\frac{2}{5}$	14 $8\frac{4}{5}$	dry	1 8
,, 19	58	48	14 $12\frac{4}{5}$	14 $8\frac{4}{5}$	dry, then wet	2 0
,, 21	60	47	14 $11\frac{5}{6}$	14 9	wet, then dry	4 2
,, 22	58	47	14 $11\frac{1}{5}$	14 9	dry	4 2
,, 23	58	52	14 $10\frac{2}{5}$	14 9	wet, then dry	4 10
,, 24	57	47	14 $13\frac{3}{5}$	14 $8\frac{4}{5}$	wet	3 2
,, 25	57	53	14 $14\frac{2}{5}$	14 $10\frac{2}{5}$	dry, then wet	2 9
,, 26	57	50	14 12	14 8	dry	4 5
,, 28	58	47	14 $14\frac{2}{5}$	14 $11\frac{1}{5}$	dry	4 6
,, 29	56	54	15 $\frac{4}{5}$	14 $12\frac{4}{5}$	dry	3 1
,, 30	57	50	15 —	14 $12\frac{4}{5}$	dry	3 0
May 1	58	46	15 —	14 12	dry	2 11
,, 2	59	43	15 $9\frac{3}{5}$	14 $13\frac{3}{5}$	dry	2 4

It is impossible, from these data, to say exactly what effect the condition of the atmosphere has on the *quantity* of gas in a mine; it must be obvious to the reader that the difference of a few ounces in pressure per square inch, and that is all we can record by the barometrical changes, cannot affect a blower of gas issuing with a force of possibly twice the pressure of the atmosphere. The question resolves itself purely into one of equilibrium; on the one hand we have a constant force exerted by the nucleus of air by which the earth is enveloped, varying, when estimated in pressure per square inch, of from 14 to 15lbs.; on the other hand, we have a discharge of gas issuing with a pressure of from 1lb. to an unknown limit per square inch; the obvious deduction is this up to 15lb., that is, that so long as the barometer stands at 30 in the pit, the atmospheric pressure counteracts 15lbs., and only that amount, of the pressure with which the blower issues; that if this latter pressure is more than 15lbs., the origin of its excessive force must be attributed to some other source than any abnormal decrease in the surface barometrical readings.

The observations illustrated by the chart are the ones I have selected from a considerable series of experiments, as being a fair specimen of the average results yielded.

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